Tariffs Can Be Structured to Encourage Photovoltaic Energy

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The solar power market is growing at a quickening pace, fueled by an array of national and local initiatives and policies aimed at improving the value proposition of customer-sited photovoltaic (PV) systems. Though these policies take many forms, they commonly include up-front capital cost rebates or ongoing production incentives, supplemented by net metering requirements to ensure that customer-sited PV systems offset the full retail rate of the customer-hosts.

Somewhat less recognized is the role of retail rate design, beyond net metering, on the customer-economics of grid-connected PV. Over the life of a PV system, utility bill savings represent a substantial portion of the overall economic value received by the customer. At the same time, the design of retail electricity rates, particularly for commercial and industrial customers, can vary quite substantially. Understanding how specific differences in rate design affect the value of customer-sited PV is therefore essential to supporting the continued growth of this market.

The purpose of this study is to broadly examine the impact of rate design on the economic value of customer-sited PV for commercial customers.[i] We focus, in particular, on 20 commercial and industrial electricity rates offered by the five largest electric utilities in California in 2007. We compute the annual electricity bill savings that would be realized on each of these rates by 24 actual commercial PV installations in California, using 15-minute interval building load and PV production data from those sites. We then compare the calculated bill savings across rate schedules and customer sites, and isolate differences related specifically to rate design, as well as differences related to other factors, including: the average cost of electricity on each rate, the customer load shape, the PV production profile, and the size of the PV system relative to customer load. After isolating the impact of rate design, as a whole, we then examine differences in the value of PV associated with specific rate design elements, including the design of both energy-based and demand-based charges.

Analytical Approach

For each combination of the 20 rate schedules and 24 PV/load datasets, we calculate the *pre-tax* value of the utility bill savings *a kilowatt-hour generated*, according to the following expression:

$$Value\ of\ PV = \frac{Total\ Bill\ without\ PV - Total\ Bill\ with\ PV}{Annual\ PV\ Energy\ Production}\ \ (\$/kWh)$$

Expressing the value of PV on a per-kilowatt-hour basis, rather than in absolute dollar terms, serves two purposes. First, it allows us to abstract from the specific size of the PV system, since it is a foregone conclusion that larger systems will generally produce larger absolute bill savings. Second, commercial customers in California and elsewhere are increasingly choosing to finance their PV systems through Power Purchase Agreements, whereby the customer purchases the PV output from a third-party owner on a per-kilowatt-hour basis; expressing the value of PV in the same units more readily allows for a direct comparison between the financial costs and benefits of PV from the customer's perspective in this instance.

We calculate the value of PV using both the actual PV production data from our 24 customer sites, as well as adjusted PV production data that has been scaled up or down so that annual PV production is equal to specific percentages of the gross annual building consumption at the site.

We refer to these percentage values as *PV penetration levels* and, in presenting our results, we focus primarily on PV penetration levels of 2 percent and 75 percent as representative boundary cases.

In general, we assume that customers remain on the same rate before and after the installation of a PV system, and that PV output is net metered according to the specific net metering rules of each utility. However, we also conduct separate analyses in which each of these assumptions is relaxed. In one alternate scenario, we calculate the value of PV under the assumption that customers choose the bill-minimizing rate before and after PV installation, from among each set of rates offered by a utility to a common class of customers (e.g., the set of rates offered by PG&E to customers with peak demands of 200-500 kW). This analysis helps to reveal which rate design feature(s) dominate in determining the optimal rate for customers with PV and also illustrates the value of offering multiple rate options to customers with PV. In another alternate scenario, we calculate the value of PV under the assumption that net metering is *not* available, in order to show the financial losses that commercial PV customers in California might bear if net metering were eliminated and replaced with an alternate compensatory structure.

Key Findings

Value of Commercial PV in California with No Rate Switching

Exhibit 1 summarizes the value of commercial PV in California for each of the 20 retail rates in our sample, at 2 percent and 75 percent PV penetration levels. The central tick-marks in the figure represent median values across the 24 PV installations, while the error bands represent the $10^{th}/90^{th}$ percentile values among our 24-customer sample.

This figure and further results presented in the report support three basic observations:

- *The value of PV varies widely across rates and customers.* At 2 percent PV penetration, the median value of PV among the 24 customers varies by nearly a factor of two across the 20 rates in our sample, from $0.10 a kilowatt-hour to $0.18 a kilowatt-hour. At 75 percent PV penetration, the variation in median values is even greater, ranging from $0.06 a kilowatt-hour to $0.18 a kilowatt-hour. This variation reflects differences in both rate *structure* as well as rate *level* (i.e., some rate schedules simply have larger charges, separate from how those charges are structured). Considering customer characteristics, reflected in the percentile bands, leads to an even broader range of PV value, from $0.05 a kilowatt-hour to $0.24 a kilowatt-hour at 2 percent PV penetration.

- *Larger PV systems, relative to building load, tend to have a lower rate-reduction value than smaller systems, on a per-kilowatt-hour basis.* As PV systems are sized to provide increasing levels of annual facility load, the per-kilowatt-hour value of those PV systems declines significantly on many rates. Overall, the median rate-reduction value of PV declines from $0.14 a kilowatt-hour to $0.12 a kilowatt-hour when PV penetration increases from 2 percent to 75 percent, a drop of approximately 20 percent. It is also evident, however, that the magnitude of this decline varies significantly among rates, with some rates seeing little to no decline in PV value.

- *The shape of a customer's load profile can impact the rate-reduction value of PV.* The spread between the upper and lower percentile bands—which are the result of variations in customer load profiles and PV production profiles—differs substantially across rates and tends to be wider at 2 percent PV penetration than at 75 percent. This indicates that the shape

of the customer's load profile and (to a much lesser extent) the PV production profile may be much more important determinants of the value of PV for some rates than others, and more so at lower PV penetration levels.

Demand Charge Savings from Commercial PV with No Rate Switching

The observations noted above are driven, in large part, by the existence of demand charges. The relative size of demand-based charges, compared to energy-based charges, can have a sizable impact on the rate-reduction value of PV. This finding is powerfully illustrated by **Exhibit 2**, which presents the *normalized[ii]* value of PV relative to a variable called the demand weight, which represents the proportion of total customer electric bills (pre-PV) that is made up of demand charges.

The figure shows that, when PV systems represent a small proportion of load, the existence of demand charges need not substantially degrade the value of PV. This is shown by the fact that, at 2 percent PV penetration, the normalized value of PV does not universally drop with increasing demand weight. In contrast, at 75 percent PV penetration, the normalized value of PV unmistakably drops as the relative magnitude of demand-based charges increase. The physical basis underlying this trend is that, at higher levels of PV penetration, the customer's maximum demand shifts to times when PV production is minimal or non-existent.

Clearly, PV systems can provide significant demand-charge savings, but these savings diminish with system size. In fact, the decline in the overall rate-reduction value of PV at higher PV penetration rates is driven almost entirely by a decline in demand charge savings. At a 2 percent PV penetration level, for example, the median value of actual (not normalized) demand charge savings is as high as $0.05-$0.07 a kilowatt-hour for 8 of the 20 rates examined, in several cases comprising more than 50 percent of the total bill savings. At a 75 percent penetration level, however, the median value of demand charge savings declines precipitously, amounting to, at most, $0.01–$0.02 a kilowatt-hour generated. As a result, at high PV penetration rates, the value of PV is dominated by energy charge savings, which do not deteriorate at higher PV penetration levels.

In addition to PV penetration level, two other factors substantially impact the ability of PV systems to reduce demand-based charges:

- *Demand charge design:* Demand charges can be differentiated from one another according to how customer demand is defined for the purposes of determining the charge. Among the rate schedules included in this report, three different measures of customer demand are used: *annual* (maximum demand over the preceding 12 months), *monthly* (maximum demand in the monthly billing period), and *time-of-day* (maximum demand in one or more time-of-day [TOD] periods within the monthly billing period). We generally find that demand reductions are much less variable, and are greater in the median case, when demand charges are based on maximum demand during the summer peak TOD period. It is also quite clear, however, that the magnitude of those demand reductions is sensitive to the particular definition of the summer peak TOD period that is used. Specifically, demand reductions are greater and, at low penetration levels, much less variable across customers, the earlier the peak period ends. As the period extends further into evening hours, it becomes more likely that the customer's peak demand will occur in hours when its PV system is producing little or no energy.

- *Customer load profile:* For a given rate schedule and PV penetration level, savings on demand charges can vary substantially across customers, indicating that the specific characteristics of the customer's building load profile and/or PV production profile can be important determinants of the value of PV. We find that, regardless of the composition of the

demand charges, customers with an afternoon peak load shape can receive substantial demand charge savings at low PV penetration levels, and modest but still meaningful savings at high PV penetration levels. In contrast, customers with flat or inverted load profiles (i.e., whose load shapes have no significant peak or peak in evening hours) earn essentially no demand charge savings on rates without TOD demand charges. On rates with a TOD-based demand charge, customers with flat or inverted load profiles may earn some modest amount of demand charge savings, but only at low PV penetration levels.[iii]

Energy Charge Savings from Commercial PV with No Rate Switching

In contrast to demand charge savings, neither the level of PV penetration nor the customer's load shape exert much if any influence on PV-induced energy charge savings. Moreover, as with demand-based charges, we find that the specific temporal profile of PV production has a moderate impact on energy charge savings, equal to less than $0.01 a kilowatt-hour in most instances.

Just as the design of demand-based charges affects the rate-reduction value of PV, however, so too does the design of energy-based charges. In particular, we find that two design elements impact the degree to which commercial PV systems in California can offer energy charge savings: the basic type of energy charge (flat, seasonal, or time-of-use [TOU]) and, for TOU-based charges, the spread between peak and off-peak prices.

Exhibit 3 presents the *normalized* value of energy charge savings for each rate, grouping the rates according to the type of energy charge used and listing the rates in order of increasing summer peak to winter off-peak price ratio. From visual inspection of this figure, we see that much of the variation in the normalized value of energy charge savings can be explained by these two rate design elements. In particular, TOU-based energy rates with relatively little spread between peak and off-peak prices offer approximately 5–10 percent greater energy charge savings than do rates with seasonal or flat energy charges, whereas those TOU rates with a much larger price spread offer more than 20 percent greater savings on energy charges than do flat or seasonal charges. The basic reason for these findings is that TOU rates provide a higher credit for PV production during summer afternoon periods, which is also when production tends to be greatest.

Optimal Rate Selection

The analysis presented thus far assumes that customers are on the same rate before and after PV installation. In reality, however, customers often have a choice of rate options and can select the rate that minimizes their bill, both before and after PV installation.

When rate switching is allowed, we find that the impact of PV penetration diminishes somewhat. Specifically, without rate switching, increasing PV system size from 2 percent to 75 percent of customer load reduces the median normalized value of solar electricity by a full 20 percent. With the assumption that customers can choose among available commercial tariffs, however, the reduction in value with higher PV penetrations drops from 20 percent to 13 percent.

We also find that, at low levels of PV penetration, customer load characteristics largely determine the optimal retail rate, and the existence of a PV system does not lead to widespread rate switching from the before-PV case. At higher levels of PV penetration, however, a substantial proportion of customers will be better off switching to an energy-focused "PV-friendly" rate.

Of the rate schedules analyzed in this paper, three have been identified as "PV-friendly" due to minimal or no demand charges: PG&E's A–6; SCE's GS–2, TOU Option A; and SCE's TOU-GS-3 Option A.[iv] Depending on its peak demand, a customer may be able to choose between one of these "PV-friendly" rates and one or more other rate options (see **Exhibit 4**). For each of the 24 customers in our dataset, we determined the optimal rate within each of the four rate groups

identified in **Exhibit 4**, across a range of PV penetration levels. **Exhibit 5** presents these results, in terms of the percentage of customers for which each "PV-friendly" rate is optimal. At PV penetration levels greater than 50 percent, all or nearly all of the customers in our sample would minimize their utility bill by switching to the "PV-friendly" rate. At low PV penetration levels, however, these "PV-friendly" tariffs would not be optimal for many customers. As such, if energy-focused rates were required of *all* commercial PV systems, then many customers wishing to install smaller PV systems (relative to load) would be disadvantaged.

The Value of Net Metering

The analysis presented thus far has assumed that PV systems are net metered. To estimate the incremental value of net metering, we also calculate the value of PV without net metering, for each combination of customer and rate schedule.

Doing so first requires stipulating how PV output would be compensated in the absence of net metering. One potential compensatory scheme, which we analyze here, is where PV production in excess of the customer's load during any 15-minute interval is either uncompensated (i.e., "donated" to the utility) or sold to the local electric utility at some pre-specified sell-back rate. Just as with net metering, all PV production up to the customer's load during each 15-minute interval is assumed to be valued at the prevailing retail rate. The only difference is in the treatment of excess PV production, above the customer's load, during each 15-minute interval.

Exhibit 6 shows the loss of value without net metering across a range of PV penetration levels, under four different sell-back rates (including $0.00/ a kilowatt-hour, where excess generation in each 15 minute interval is donated to the utility). For each scenario, the figure shows the distribution of the loss of PV rate-reduction value (median and $10^{th}/90^{th}$ percentile values) across all combinations of rates and load/PV datasets.[v]

Several key findings emerge from this analysis.

- First, eliminating net metering can significantly degrade the economics of PV systems that serve a large percentage of building load. Under the assumptions stipulated in the report, we find that an elimination of net metering could, in some circumstances, result in more than a 25 percent loss in the rate-reduction value of commercial PV.
- Second, at PV penetration levels of less than 25 percent, net metering provides little incremental value to the customer, compared to the alternate compensatory structure described above. This occurs because, at low penetration levels, little to no net excess PV generation occurs over the course of the year, and therefore all or almost all of the PV production is valued at the full retail rate.
- Third, not surprisingly, the loss of value without net metering is highly sensitive to the sell-back rate, with lower sell-back rates leading to greater losses.
- Fourth, the potential economic loss from eliminating net metering is greatest under what might be considered the most "PV-friendly" retail rates: those with low demand charges.
- Finally, customers with flat or inverted load shapes have more to lose from the elimination of net metering than do those customers with more typical afternoon peaks, assuming that the treatment of PV production in the absence of net metering is similar to what is posited here. Customers with load shapes that match PV production profiles depend less on net metering, and thus are able to host proportionately larger PV systems without experiencing significant erosion in value if net metering is eliminated.

Conclusions

As described above, the importance of rate design for commercial PV systems goes well beyond the availability of net metering. Instead, the specifics of the rate structure, combined with the characteristics of the customer's underlying load and the size of the PV system, can have a substantial impact on the economics of customer-sited commercial PV systems. It is therefore important that utilities, their regulators, and other stakeholders consider the potential impact on the solar market when establishing or revising retail rates.

NOTES

[i] The results presented in this article are drawn from a lengthier report published by Lawrence Berkeley National Laboratory, entitled *The Impact of Retail Rate Structures on the Economics of Commercial Photovoltaic Systems in California*, available at http://eetd.lbl.gov/ea/emp/re-pubs.html.

[ii] To isolate the impact of differences in rate structure, the value of PV for each customer-rate combination can be normalized to control for differences in the magnitude of charges on each rate. We calculate the normalized value of PV by first dividing the value of PV for each customer-rate combination by the median cost of electricity on that rate across all 24 customers, prior to PV installation. We then multiply this value by the median cost of electricity across all combinations of the 24 customers and 20 rates (again, without PV). It is important to note that it is the relative value of these normalized results that matters; the specific numerical values have no particular meaning.

[iii] Interestingly, we find that the specific shape of the PV production has a relatively modest effect on the value of demand charge savings.

[iv] Though PG&E's A-1 rate has no demand charges, it is not designated as "PV-friendly" in this report because other available rates are more attractive to all 24 of the customers in our sample, at all levels of PV penetration. LADWP similarly offers an otherwise "PV-friendly" rate with low demand charges (A-2, D), but that rate is not available with net-metering, making it very unattractive at high levels of PV penetration. As a result, that rate was not included in our analysis.

[v] The loss of value of PV without net metering is negative (that is, losing net metering is beneficial) in cases where the sell-back rate is greater than the value of PV with net metering.